PLANTING DATE, STORAGE AND GIBBERELLIC ACID AFFECT DORMANCY OF *ZANTEDESCHIA* Spreng. HYBRIDS

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ABSTRACT

To match the supply of *Zantedeschia* cut flowers and tubers to the demands of the international market, crops have to be timed to a schedule, which requires control of the growth cycle and, in particular, dormancy. In order to improve the predictability and accuracy of timing of *Zantedeschia*, the effect of different planting seasons and two dormancy-breaking treatments were tested on cultivars 'Black Magic' and 'Treasure', which were known to have a contrasting level of dormancy. Tissue-cultured plants were ex-flasked in July and November 1999, and grown for 180 days in a heated glasshouse (first cycle). Between 120 and 180 days of growth, plants were harvested at 15 days intervals, and tubers cured. Subsequently, tubers were stored for 0 or 3 weeks (10 ± 1°C; 70-80% RH) and dipped in 100 $mg \cdot L^{-1}$ gibberellic acid plus surfactant or water plus surfactant, prior to planting for dormancy assessment (second cycle).

Growing the plants with four months difference in planting date did not cause major alteration in the occurrence of dormancy. Dormancy was brought forward by up to 10 days after the November date of ex-flask, but this was most likely to be due to higher temperatures during that period. In contrast, depth of dormancy varied between cultivars, with 'Black Magic' taking in average 16 days longer to emerge than 'Treasure'. Storage partially released bud dormancy of the tubers. It increased emergence to over 80% regardless of the time of harvest in the first cycle and cultivar, but reduced time to emergence mostly after harvests at 180 days. Furthermore, following storage, time to emergence was reduced to over 50 and 30 days for 'Black Magic' and 'Treasure', respectively, which exceeded the commercially acceptable period to emerge. Gibberellic acid also broke bud dormancy, improving emergence to over 80%, and reduced time to

emergence to between 29 and 57 days, irrespective of the time of harvest in the first cycle and cultivar. The effectiveness of gibberellic acid at any time following harvest during the first cycle, may imply that dormancy of *Zantedeschia* is not as deep as in temperate woody plants.

Cessation of leaf emergence in the first cycle was found not to be directly related to the occurrence of dormancy. Degree-days, on the other hand, presented a possible alternative to predict this process. It was estimated that deepest dormancy of 'Black Magic' occurred between 2614 and 2732 °C-days after planting, while deepest dormancy of 'Treasure' occurred between 2681 and 2839 °C-days after planting.

The present study presents storage and gibberellic acid as possible options to control dormancy, and the use of degree-days to predict the occurrence of this process. Further research is necessary to develop these options as commercially applicable practices, and to further clarify the process of dormancy in *Zantedeschia*.

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1. INTRODUCTION

1.1 Commercial significance of Zantedeschia.

Zantedeschia spp. Spreng. is currently the second largest cut flower export for New Zealand after *Cymbidium* orchids, with a value of 4,5 million dollars being exported in the year to June 1999 (Topless, 2000). The counter-seasonality of the production in the Southern Hemisphere allows growers to supply lucrative export markets in the Northern Hemisphere during peak demand (Clemens et al., 1999).

Field production of *Zantedeschia* flowers in New Zealand is highly seasonal, extending from November through to March (Clemens & Welsh, 1993), with a peak in December/January (Muller, 1993). The high supply of flowers during the peak period has a negative impact on international prices, which consequently reach a minimum over the Christmas-New Year period and start to recover from mid-January onwards. Therefore, growers have been encouraged whenever possible to time their plantings to take advantage of the higher prices which occur in the shoulders of the season, i.e. October, November, February, March and April (Muller, 1993).

An additional market for *Zantedeschia* flower growers and specialist propagators is the sale of tubers on the export market (Clemens & Welsh, 1993). These growers purchase tubers for pot forcing or cut flower production for sale at Christmas, New Year and Valentines, which implies that New Zealand growers need to be able to supply tubers during October-February, i.e. the normal growing season in the southern Hemisphere.

To supply the constant demand of the international market, the *Zantedeschia* cut flower and potted plant industries must aim to attain all year production, which implies the manipulation of the timing and duration of the plant's natural growth cycle (Halligan et al., 1995; Brooking et al., 1998). However, as it will be shown in this introduction, negative results of practices applied to manipulate the duration of the growth cycle of *Zantedeschia*, and a lack of knowledge on the factors that control dormancy, have made accurate timing of the crop difficult to achieve.

1.2 Origin and distribution of Zantedeschia *genus.*

The majority of New Zealand's production is limited to the summer calla, a term that groups the species *Zantedeschia jucunda* Letty, *Z. pentlandii* (Wats.) Wittm., *Z. rehmannii* Engl. and *Z. elliotiana* (Wats.) Engl., and the hybrids resulting from interespecific crosses. Therefore, the following review is limited to these species.

The genus *Zantedeschia* corresponds to a group of geophytic plants endemic to the African continent. It is most prevalent to the southern regions (i.e., Cape Province, Orange Free State, Natal, Lesotho, Swaziland, Transvaal), but also extends into Zimbabwe, Malawi, Nigeria and Angola (Letty, 1973). Summer calla plants grow in mountainous regions, at altitudes of 1200 to over 2000 m, generally in grassy slopes and at forest margins.

Distribution of the summer calla is restricted to cool-temperate climates, with a mean air temperature of 11 °C during June-July (min. 2.7 °C; max. 20 °C), and 20 °C (min.

14 °C; max. 27 °C) from October through to March (Funnell, 1993a). Rainfall is predominantly distributed during the summer.

1.3 Cyclic periodicity.

A major feature of geophytes (i.e. plants that survive using specialised underground storage organs) is the development of a cyclic behaviour or periodicity, which typically matches their phenologic cycle to the climatic conditions (Rees, 1972; 1984). It is believed that periodicity evolved as a survival means to overcome unfavourable climatic conditions in seasonal climates, allowing the plant to renew activity when conditions improved (Rees, 1981).

The close relationship between environment and periodicity of a plant is still evident in the behavior of commercial geophytic flower crops. A general example is the division of geophytes into spring-, summer- and autumn-flowering plants made by horticulturists, according to the time of the year when active growth and flowering is expressed (e.g. De Hertogh & Le Nard, 1993). Although broad, this division shows the behaviour that the plants would have had in their natural habitat, and the requirements that have to be met to grow them successfully. A more specific example are the commercial varieties of *Tulipa* sp. L., which retain within their genotype those attributes which fitted their ancestors to the harsh habitat of the uplands of Asia Minor (Rees, 1981). In those areas, winters are severe with deep snow, the springs are short and moist and the summers and autumns dry and hot. Consequently, tulip plants evolved into spring flowering with no aerial growth in summer and the resumption of aerial growth once the cold requirement has been fulfilled.

As a response to cool and dry winters and summer rainfall, *Zantedeschia* species also developed a seasonal periodicity, with complete foliage senescence during winter, while growth and flowering occur during late spring through summer (November-January) (Letty, 1973; Funnell, 1993a; Figure 1). A compact, disc-shaped rhizome -also called a tuber or corm[1]- is the structure which survives under the ground during dry periods (Corr, 1993).

As with tulips, the seasonal periodicity of *Zantedeschia* is also evident in commercial crops, where it follows basically the same cycle as in its native habitat. In a normal production cycle in the Southern Hemisphere, *Zantedeschia* tubers are planted in September/ October, flowering from November through to March (Clemens & Welsh, 1993; Halligan et al., 1995). The new foliage stops appearing in February, and by April/ May leaf senescence of the plants begins (Figure 1).

[1] The term tuber will be used in this review to avoid confusion.

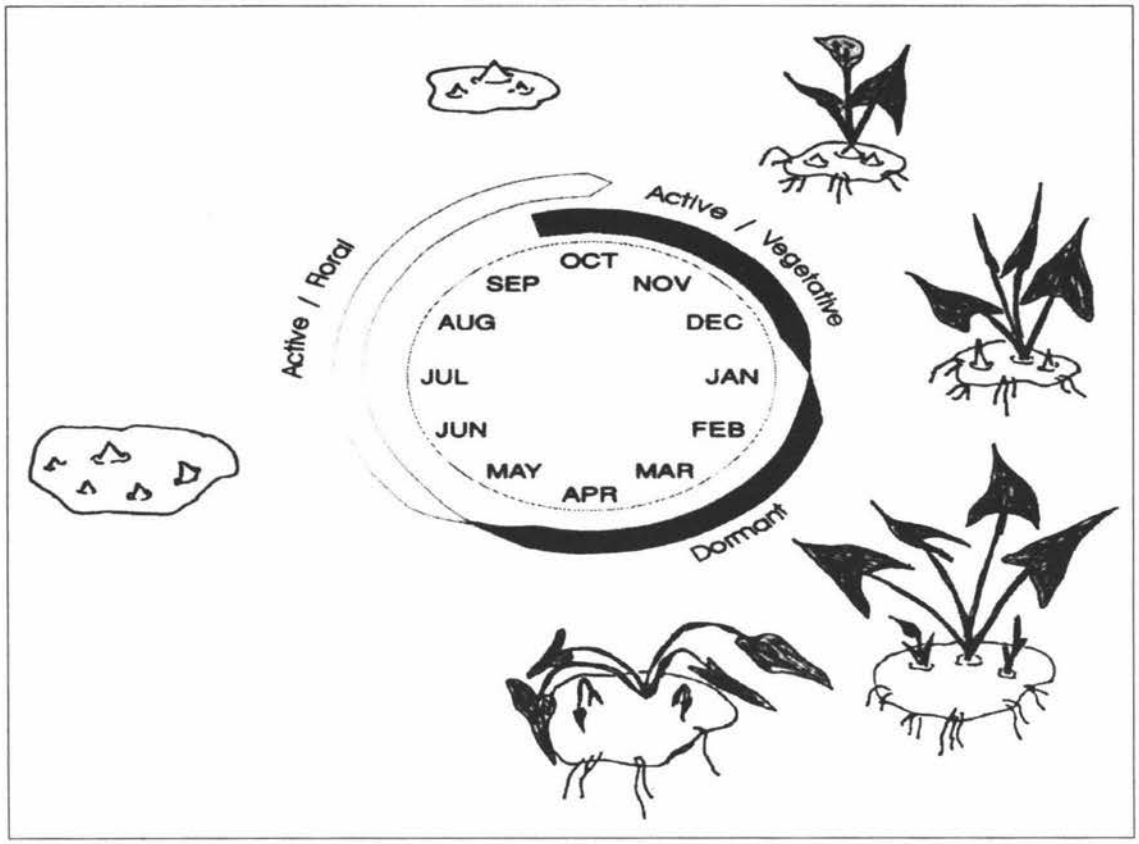

Figure 1. Twelve-month cycle representing the phases of development of the apical meristem in a dominant bud of *Zantedeschia* 'Black Magic', grown at Palmerston North, New Zealand. The visible state of the plant is also depicted throughout the cycle (modified from Halligan et al. (1995).

1.4 Dormancy.

Dormancy is an integral part of the annual cycle of most geophytes, characterising perennial plants that exhibit seasonal growth (De Hertogh & Le Nard, 1993). Lang et al. (1987) defined dormancy as '*the temporary suspension of visible growth of any plant structure containing a meristem*', and divided it into three types. These types are: eco-, para- and endo-dormancy, representing dormancy controlled by conditions outside the

plant, outside the affected organ but within the plant and within the organ, respectively (Dennis, 1996). Although not universally accepted (Rowland & Arora, 1997), Lang's terminology has been qualified as more physiologically descriptive than most of the earlier terminology and, therefore, it will be used in this study.

Additionally, endo-dormancy can be further divided into two consecutive phases. The first corresponds to deep endo-dormancy, and is based on the inability to induce the buds to grow under natural conditions (Faust et al., 1997; Figure 2). The second is a shallow endodormant period, which is the stage where dormancy can be overcome by artificial treatments.

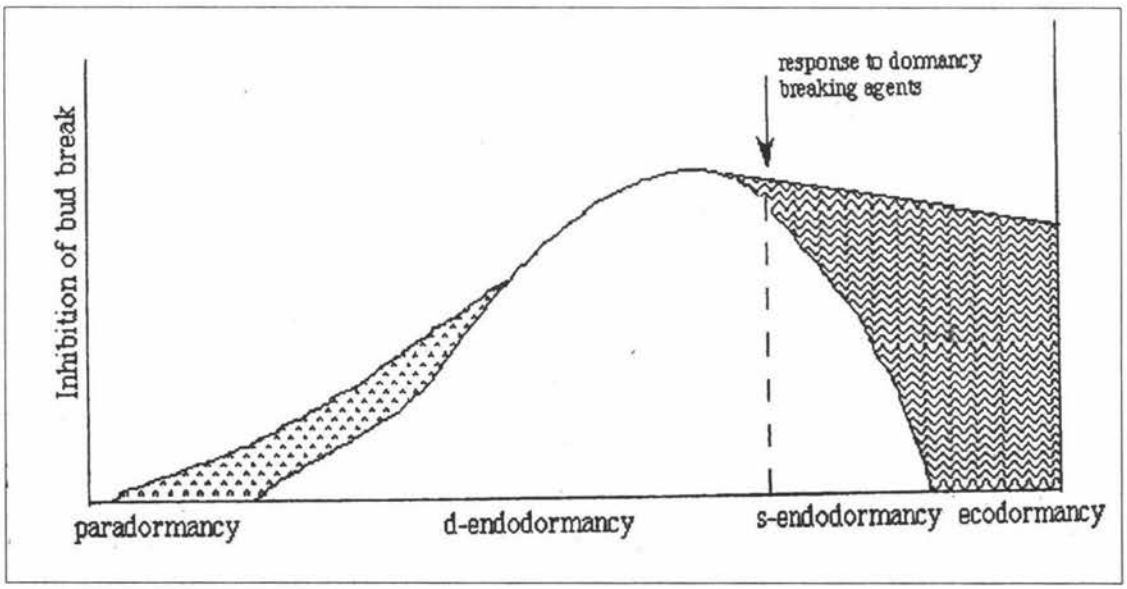

Figure 2. A schematic representation of inhibition of budbreak during dormancy. Dormancy begins with para-dormancy and it deepens during deep endo-dormancy (d-endo-dormancy). When endo-dormancy weakens during shallow endo-dormancy (s-endodormancy), buds respond to dormancy-breaking treatments. The depth and duration of eco-dormancy is environment dependent. (From Faust et al., 1997).

There has been some debate concerning dormancy of *Zantedeschia* (Kuehny, 2000). Early studies suggested the absence of a dormant period unless it was artificially induced by drying, and that year-round production of flowers could be achieved in greenhouses under protection (Post, 1959; Wilkins, 1985). This theory was later refuted by Corr & Widmer (1988), who demonstrated that *Zantedeschia* does have a dormant stage, since tubers replanted immediately after leaf removal were not able to sprout even if placed under ideal environmental conditions. Halligan et al. (1995) observed that this dormant period lasted from late summer (January), when leaf production stopped, to autumn (late April/ early May) (Fig. 1). During this period, the apical meristem was incapable of continued growth until dormancy was released.

It is not known if bud dormancy of *Zantedeschia* tubers corresponds to endo- or para-dormancy. Previous studies reported the ability of buds to continue developing once isolated from the rest of the tuber and placed in agar (Halligan et al., 1994), which suggests the occurrence of para-dormancy. However, it has not been possible to confirm these results in later experiments, due to contamination of the material. In order to avoid misinterpretations, the term dormancy in the present study will refer indistinctly to endo- or para-dormancy.

1.4.1 Horticultural importance of dormancy

The existence of a dormant period is convenient for horticultural purposes, since it permits easy handling, storage and transport of the bulbs[2] (De Hertogh & Le Nard, 1993). Furthermore, it can be overcome by natural or artificial means at a predetermined time,

[2] The term bulb here includes all geophytes with diverse storage organs

which allows growers to control timing of production or flowering independently from the natural season to which the plant alone is constrained (Rees, 1981). Means of overcoming dormancy include storage of the bulbs and the use of growth regulators. In addition, timing of the production can be controlled through early lifting practices, which bring forward the occurrence of dormancy, allowing growers to harvest and handle the bulbs earlier in the season.

Although being an extensively used practice, timing of bulb or flower production through storage and early lifting has not been successfully achieved with all geophytes. As it will be explained with more detail in the following pages, these practices have even resulted in negative responses when applied to *Zantedeschia* crops. Since the environmental and /or genetic factors that control dormancy in *Zantedeschia* are not known, it has not been possible to develop the best techniques to control the duration and occurrence of dormancy, and consequently, to accurately time the flower and bulb production. A more complete knowledge of dormancy of this crop would greatly improve possibilities of timing the production to the needs of the market.

From a horticultural viewpoint, not only it is important to control the duration and occurrence of dormancy, but also it is essential to be able to visually detect when dormancy occurs. If detectable, the best lifting time and the most effective moment to apply dormancy-breaking treatments can be programmed. Nevertheless, to date the only visual change that might possibly be linked to dormancy is the cessation of leaf emergence and the subsequent onset of foliage senescence during the summer (Halligan et al., 1995).

1.4.2 Factors influencing dormancy onset.

Environmental factors that induce dormancy vary with the species and their native environment. For the majority of the woody plant species from temperate climates, short days and cold temperatures cause the cessation of extension growth and the formation of resting buds (Wareing & Saunders, 1971; Wareing & Phillips, 1981; Olsen et al., 1995). For some bulbous species, such as *Gladiolus grandiflorus* Hort., corm development is also stimulated by short days (Hartmann et al., 1997). For others, like onion (*Allium cepa* L..) and *Poa bulbosa* L.. -a grass geophyte with summer dormancy-, bulb production and leaf senescence, which are considered as indicative of the onset of dormancy, are induced by long days (Ofir & Kigel, 1998). Dormancy of tulip bulbs, on the other hand, is triggered by high temperatures (Rees, 1972).

Although periodicity of growth and development in *Zantedeschia* has been studied (e.g. Funnell & MacKay, 1987; Halligan et al., 1994, 1995), the factors that induce the cessation of leaf production and, possibly bud dormancy, have not been identified yet. In addition, most of the research regarding the influence of the environment on *Zantedeschia* has focused on growth and flowering, and their effect on dormancy can only be inferred.

1.4.2.1 Photoperiod

Photoperiod plays an important role in both vegetative and reproductive growth of plants, since it influences processes such as seed germination, stem elongation, leaf growth, senescence, abscission and dormancy (Coleman & Chen, 1996). The adaptive value of using photoperiod as a timekeeping mechanism for synchronising growth transitions is evident, since it is the one environmental cue that does not vary from year to year.

There is little evidence of photoperiodic control of dormancy in ornamental bulbs, which is in sharp contrast to that shown in the buds of many woody plants (Rees, 1981). Up to now, there is confirmation of day-length effects only on dormancy of *Allium* species (Rees, 1972; Wareing & Phillips, 1981), *Gladiolus* (Hartmann et al., 1997), *Begonia x tuberhybrida* Voss. (Lewis, 1951) and *Dahlia pinnata* Cav. (De Hertogh & Le Nard, 1993).

Early studies by Greene et. al. (1932; cited by Dole & Wilkins, 1999), as well as observations by commercial growers, indicated that there are no photoperiodic effects on *Zantedeschia*'s growth (Ball, 1986; Corr & Widmer, 1990) and dormancy (Funnell, 1988). In a later unpublished experiment, Brooking et al. (1998) confirmed that photoperiod did not affect the induction of dormancy, since plants remaining in a glasshouse under declining daylength, and plants transferred to a long-day environment entered dormancy at the same time. Therefore, *Zantedeschia* plants should be able to grow under any daylength conditions.

1.4.2.2 Light intensity

Light has been related to the release of dormancy in seeds of several species, such as lettuce (*Lactuca sativa* L.) (Wareing, 1982), celery (*Apium graveolens* L.) endive (*Chicorium endivia* L.) (Khan, 1996) and *Arabidopsis thaliana* L. (Cone & Spruit, 1986). However, there is no evidence of this factor affecting the onset of dormancy.

Few studies have investigated the effect of light intensity on growth and development of *Zantedeschia*. Warrington & Southward (1989) and Funnell (1993a) found that, under a constant temperature and low light conditions (350 μmol $s^{-1}m^{-2}$), leaf area expansion was extended and leaf senescence delayed, as compared with high light

intensity (700 μmol $s^{-1}m^{-2}$). However, neither of the experiments measured any parameter that could directly be related to the onset of dormancy. In addition, both experiments were carried out in controlled environment rooms, and it has been suggested that the observed response may be related to photoassimilate partitioning and not necessarily to dormancy (Funnell, pers. comm.).

As shown in this section, there is no information that associates light intensity with the induction of dormancy on *Zantedeschia*. However, studies with other species suggest that these two factors may not be directly related.

1.4.2.3 Cultivars

Length and depth of dormancy of many species is largely under genetic control. For example, cultivar- and species-dependent periods of dormancy have been noted in potato (*Solanum tuberosum* L.) and yam (*Dioscorea alata* L.) (Turnbull & Hanke, 1985; Burton, 1989) onion (Carter et al., 1999) and *Dahlia* (Konishi & Inaba, 1967 cited by De Hertogh & Le Nard, 1993).

In *Zantedeschia*, it appears that there is significant variation in both tuber maturation and dormancy among cultivars (Halligan & Fulton, 1998). Reports show that tubers of the cultivars 'Treasure' and 'Cameo' were able to sprout within 1.5-3 weeks when replanted without a storage period. In contrast, tubers of the cultivars 'Black Magic' and 'Dominique' sprouted after a minimum of sixteen weeks or failed to sprout altogether.

In addition, a difference of 7-8 weeks in the occurrence of cessation of growth and leaf senescence between cultivars 'Black Magic' and 'Pink Persuation' (Clemens & Welsh, 1993), suggests that timing of the onset of dormancy may also depend on the cultivar.

1.4.2.4 Temperature

Of the various climatic variables to which a plant is exposed, temperature has been considered as a major environmental factor determining variations in growth (Piñera, 1995) and development (Terry, 1968; Passian & Lieth, 1994). Higher temperatures generally lead to the earlier onset of a phenological event, like time to flower of *Hibiscus moscheutus* (Wang et al., 1998), *Dahlia pinnata* (Brøndum & Heins, 1993) and rose (*Rosa x hybrida* L.) (Pasian & Lieth, 1994), while low temperatures suppress processes such as sprouting of potato tubers (Suttle, 1995).

Warmer temperatures lead to a chronologically earlier onset of all events in growth and development of *Zantedeschia*, including shoot and leaf appearance, flowering, rapid tuber growth, cessation of leaf appearance and leaf senescence (Funnell, 1993b). For instance, *Z. rehmannii* plants grown at an ambient temperature of 20 °C flowered approx. 18 days earlier than plants grown at 15 °C (Corr & Widmer, 1990). Similarly, senescence was advanced by 60 days in plants grown at high temperature (28/22 or 22/16 °C day /night), as compared with plants grown at low temperature (16/10 °C) (Warrington & Southward, 1989; Funnell, 1993a). If we assume that there is a relation between cessation of growth and dormancy, then this could indicate that the onset of dormancy is probably also affected by the temperature regime.

1.4.2.4.1 Temperature as a predictor of the occurrence of dormancy

Given the importance of dormancy on timing and scheduling floricultural crops, the ability to predict its occurrence is essential for growers who aim to supply the international market during highest demand. In many temperate woody species, prediction of dormancy does not represent an obstacle, since the factors that trigger the process are well known (refer to section 1.4.2). However, prediction of dormancy in *Zantedeschia* has not been possible since, as shown in this chapter, the environmental and/or physiological factors involved in its induction have not been identified. Thus, the accumulation of temperature by the plant, measured as degree-days, may be a useful tool for the prediction of the occurrence of dormancy.

1.4.2.4.1.1 Degree-Days

Heat units, measured in growing degree-days, relate the accumulation of heat energy by a crop during a given period to the progress in development or growth processes (McMaster & Wilhelm, 1997). This system is currently being used to monitor growth and development of many crops (O'Rourke & Branch, 1987), and has vastly improved description and prediction of phenological events as compared to other approaches, such as time of the year or number of days (McMaster & Wilhelm, 1997).

There are no precedents on the use of degree-days to monitor growth and development, or to predict the occurrence of dormancy in *Zantedeschia* plants. However, interpretations of the studies carried out by Halligan et al. (1995) and Halligan & Fulton (1998), and the temperatures recorded during their experiments, lead to suggest that the onset and release of dormancy may occur between 1000-1600, and between 2600-2900 °C-days, respectively (Appendix 1).

1.4.3 Manipulation of dormancy

1.4.3.1 Early lifting practices

Early lifting of geophytic crops may provide a means of reducing the need for long-term storage, to supply tubers and flowers for early season exports (Funnell & MacKay, 1989). Practices applied for early lifting include mechanical removal of the foliage and promotion of early foliage senescence by means of herbicide application and withholding water.

Studies performed on early lifting of *Caladium* x *hortulanum* L.. showed that foliage mowing was effective in reducing weight of roots and shoots of the plants (Gilreath & Harbaugh, 1986). The application of herbicides like paraquat, oxyfluorfen and, to a minor extent, ethephon, was equally effective in promoting foliage senescence without affecting growth in the subsequent cycle.

Although both *Caladium* and *Zantedeschia* belong to the *Araceae* family, the use of the same practices, as described above, on *Zantedeschia* crops has resulted in negative outcomes. Plants subjected to foliage mowing and subsequently left under conditions favorable for sprouting, were not able to resume growth until they were lifted and their roots removed (Corr & Widmer, 1988; Brooking et al., 1998). In contrast, tubers that were lifted and cured or stored grew soon after being replanted (Corr & Widmer, 1988; Brooking, Pers. Comm).

Similarly, the artificial induction of foliar senescence through withholding water caused slow and erratic emergence during the following growth cycle (Funnell & MacKay, 1989). In addition, the application of ethephon did not induce foliage senescence, and

progressive increases in the doses resulted in a reduced increase in tuber dry weight. Since export tubers, like cut flowers, have to meet quality standards such as high quality flowers and productivity and flowering programmability (New Zealand Calla Council, 1994), erratic emergence represents a serious problem for exporters.

Practices to promote early senescence of the foliage are thought to induce dormancy of buds on tubers of *Zantedeschia* (Corr & Widmer, 1988). This would explain the poor results obtained. Clearly, it will be necessary to fully understand the natural periodicity and dormancy of this species before being able to develop techniques for the early lifting of the plants.

1.4.3.2 Storage duration and temperature

Storage of *Zantedeschia* tubers is currently used to facilitate production programming for both pot plant and cut flower production (Funnell & Go, 1993). While the primary objective of long term storage is to allow scheduled planting and flowering by inhibiting shoot growth, the aim of short-term storage is to break bud dormancy of the tubers. In the past years, a considerable amount of research focused on the effect of storage duration and temperature on subsequent performance of *Zantedeschia*, but only a few investigations dealt with its effect on bud dormancy, and mostly non-dormant tubers were used. Only recently dormancy has become a major subject in research related with storage.

Earlier investigations suggested that dormancy of *Zantedeschia* could be overcome with storage at 20 °C for several months (Cohen, 1981). The effects of a storage period on dormancy release were later confirmed by MacKay (1985), who determined that time to

emergence of cultivars 'Pink Persuation' and 'Pacific Pink' could be reduced by 45-50 days if tubers were stored for two weeks at 5-7 °C. Likewise, a reduction in time to emergence of approx. 50% was observed in cultivar 'Black Magic', when storage duration was increased from 0 to 3 weeks at 10 °C (Halligan & Fulton, 1998).

As for the optimum temperature to break dormancy, no differences in the release of dormancy were found between tubers stored either at 10 ° or 20 °C (Brooking, Pers. Comm.). Similarly, no significant effects on growth were found on tubers of *Z. elliottiana* and *Z. rehmannii* after a storage period of six weeks at 4, 9 or 22 °C, although the highest temperature largely reduced fresh weight of the tubers, and dormancy of the tubers had been already partially released (Corr & Widmer, 1988). Thus, it would be advisable to use temperatures close to 10 °C, in order to avoid high water losses during the storage period.

Storage duration also influences time to sprout and the plant's final performance. Storage of dormant tubers for nine weeks increased time to sprout by 200%, compared with tubers stored for 0, 3 or 6 weeks (Halligan & Fulton, 1998). Additionally, storage for six months reduced flowering potential of the tubers up to 100% if gibberellins were not applied (Funnell & Go, 1993). In contrast, a minimum storage period of three weeks has shown to be effective in breaking dormancy of cultivars with deep dormancy (Halligan & Fulton, 1998), as well as in increasing plant height, number of leaves and shoots per tuber (Corr & Widmer, 1988).

1.4.3.3 Gibberellins

Among the phytohormones involved in growth and development of plants, gibberellins are the hormones most commonly associated with dormancy release (Wareing

& Phillips, 1981). When exogenoulsy applied, they have proved to be effective in breaking dormancy of seeds (Desai et al., 1997), buds (Saure, 1985), *Lilium* sp. L.. bulbs (Ohkawa, 1979; Niimi et al., 1988), and potato tubers (Tsukamoto et al., 1961; Wiltshire & Cobb, 1996), among other crops.

In Zantedeschia, gibberellin application has been widely used for the promotion of flowering (e.g. Funnell et al., 1988; Corr & Widmer, 1990; Funnell & Go, 1993; Dennis et al., 1994). Its application increases flower production through an increase in the number of buds emerging as primary shoots (Funnell & Go, 1993), and also induces flowering in tubers that otherwise would not be able to flower due to reduced size or prolonged storage (Funnell et al., 1988). Nevertheless, their possible effect on dormancy release has not been studied.

In potato crops, gibberellin concentrations recommended to break dormancy range from 1 $mg \cdot L^{-1}$ (Contreras, Pers. Comm.) to 50 $mg \cdot L^{-1}$, depending on the cultivar and storage duration (Dean, 1994; Centro Internacional de la Papa, 1988). On the other hand, concentrations used to promote flowering of non-dormant *Zantedeschia* tubers varies between 50 $mg \cdot L^{-1}$ and 600 $mg \cdot L^{-1}$ (Funnell et al., 1988; Reiser & Langhans, 1993; Dennis et al., 1994) when applied as a preplanting dip. However, the concentrations that would be most effective in breaking dormancy of *Zantedeschia* tubers are unknown.

1.5 Summary and objectives

One of the aims of the *Zantedeschia* cut flower and potted plant industries is to match the supply of flowers and tubers to the constantly increasing demand of the

international market. To achieve this, crops have to be timed to a schedule, which often implies the artificial shortening of the growth cycle, or the extension of the period of inactivity. In other species, cultural practices to manipulate the duration of the growth cycle such as early lifting and storage are widely used, but their application on *Zantedeschia* crops have not provided the predictability and accuracy desired.

Studies have been carried out to clarify *Zantedeschia* periodicity, aiming to develop more effective techniques of manipulating the growth cycle (Halligan et al., 1994 & 1995). In these studies, special attention has been paid to dormancy, since its occurrence determines the duration of the growth cycle and the storage requirements of the tubers, and consequently, the possibilities of crop scheduling. As shown in this review, the environmental and /or genetic factors that control dormancy have not been determined, but there is evidence that photoperiod and light intensity are not involved in its induction (Brooking et al., 1998; Funnell, 1993a), and that temperature can bring forward or delay its occurrence (Funnell, 1993b). In addition, it is known that the intensity of the process is highly dependent on cultivars (Halligan & Fulton, 1998). Short-term storage has been successfully tested as a treatment to artificially release dormancy of *Zantedeschia* (Halligan & Fulton, 1998), but there is no information on the efficacy of gibberellic acid, which has been used to break dormancy of numerous other crops. In addition, if the occurrence of dormancy could be visually determined or predicted by means of degree-days, this would greatly aid to program lifting of the crop and the application of dormancy-breaking treatments.

Despite the advances that have been achieved in the control of growth and periodicity of *Zantedeschia*, there are several questions that have to be answered before

timing and scheduling can reach the level of predictability and accuracy as in other geophytic crops, e.g. tulips. In order to answer some of them, the following study aims to:

- Quantify what changes in timing and duration of vegetative growth and dormancy result from a modification on growth season of *Zantedeschia* hybrids;
- Determine differences in the occurrence of bud dormancy between two cultivars known to differ in their depth of dormancy;
-Determine if dormancy duration can be modified by storage and gibberellin application and,
- Test the possibility of using cessation of leaf emergence and degree-days as indicators of the occurrence of dormancy.